NOTES ON THE GEOLOGY OF CARRIZO MOUNTAIN AND VICINITY, SAN DIEGO COUNTY, CAL.[1]

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CONTENTS

INTRODUCTION

Through the courtesy of Dr. J. C. Merriam, of the University of California, and Dr. Stephen Bowers, of Los Angeles, small collections of fossil corals and mollusks from the vicinity of Carrizo Mountain, San Diego County, Cal., were sent to Dr. T. Wayland Vaughan and Dr. Ralph Arnold,[2] of the U.S. Geological Survey, during the autumn of 1903. The material in these collections proved to be of exceptional interest to the paleontologists, and in order that a larger amount might be obtained for study and more definite information secured about the geology of the region, Dr. Bowers and the writer visited the field during the latter part of January, 1904.

[1] Published by permission of the Director, U.S. Geological Survey.

[2] A brief preliminary statement of the conclusions reached by Drs. Vaughan and Arnold after an examination of these collections appears in *Science*, N.S., XIX, No. 482 (1904), 503. At that time the fauna was regarded as lower Miocene; later conclusions are to the effect that it is upper Miocene.

A light camping equipment was secured at Imperial and the drive made to Carrizo Mountain from this point. One day was spent at the Yuha Oil Well, studying the stratigraphy and collecting, then camp was established at Coyote Well on the Jacumba Springs Road. From this point Alverson Canyon and the southern slopes of Carrizo

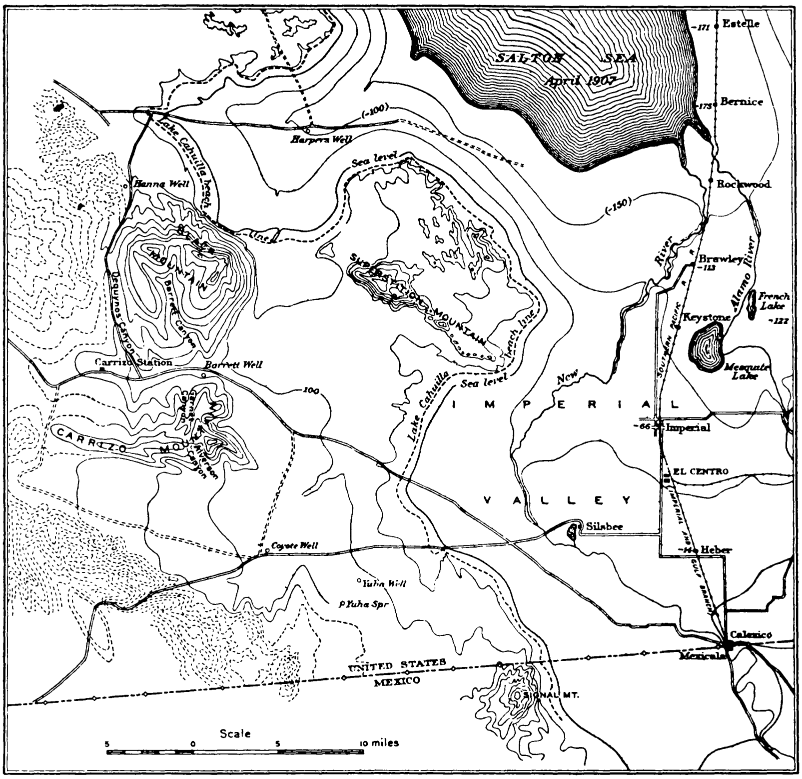

FIG. 1.—Sketch map of Carrizo Mountain and vicinity.

Mountain were accessible. Two days were utilized in work in this vicinity. Camp was then re-established about two miles below Carrizo Station, on the old stage road from Yuma to San Diego via Julian. From this point Garnet Canyon and the north slopes of Carrizo Mountain and Barrett Canyon and the south slopes of Black Mountain could be reached readily. After representative collections, amounting in all to about 1,500 pounds of material, had been made from the several fossil localities visited, the return trip to

Imperial was accomplished and the party disbanded. About ten days in all had been spent in the field.

Early Land Office maps, upon which neither roads nor relief are shown, were at that time the only official maps available, although since then, because of the rapid settlement of the Imperial Valley and the interest created in the region by the partial filling of the Salton Sink, the Geological Survey has issued a Reconnaissance Map which contains some details in the settled parts of the district but is very general in the vicinity of Carrizo and Black mountains, because these masses lie to the west of the area actually surveyed.

In 1900 and 1901 a number of oil companies were organized to prospect along the west side of the desert, between the base of the Santa Rosa Mountains and the Mexican line, and a number of engineers entered the district in the employ of these companies. Mr. I. A. Hubon and Mr. C. S. Alverson, of San Diego, were among these, and they collected data which, when assembled in a sketch map at Dr. Bowers' request, served to guide us in our field-work. From all these sources and from some sketches made by the writer the accompanying generalized map (Fig. 1) has been prepared. It does not pretend to topographic accuracy but indicates merely general geographic relations and general topographic facts without detail.

GEOGRAPHY

Black and Carrizo mountains, known also as Fish Creek and Coyote mountains, are eastern outliers of the Peninsula Range that separates the depression occupied in part by the Gulf of California from the Pacific Ocean. They are in southeastern California near the western edge of the Colorado Desert, and from fifteen to thirty miles north of the international boundary. East of them the Colorado Desert, much of it below sea-level, extends to the Colorado River, while to the west low ridges extend to the base of the main Peninsula Range.

The two masses are separated by the valley of Carrizo Creek. This stream rises in Mexico, flows north for several miles, through a high valley in the Peninsular Mountains, then descends to the Desert level through a precipitous canyon. Nearly all of that part of its channel that lies within the desert is dry except during rare

flood periods, when its waters join those of San Felipe Creek, north of Black Mountain, and eventually reach the Salton depression. At Carrizo Station, one of the relief stations of the old Butterfield stage line, a series of springs rise, and for one or two miles below this point flowing water is found in the creek bed, except during the hottest period of summer.

The desert floor at the eastern base of the peaks is generally from 100 to 200 feet above sea-level, but on the north side of Black Mountain the sea-level contour and the old beach of Lake Cahuilla,[1] 40 feet above sea-level, swing in against the mountain base. In the past the region has been rather difficult of access, because of its remoteness from settlements and its aridity. With the colonization of the Imperial Valley since 1900 and the building of the branch railroad from Old Beach to Calexico, however, this condition has been greatly modified. Now Carrizo Station or Coyote Well may be reached by one day's drive from Imperial or El Centro, and supplies are readily secured at many points in the valley. The old roads from the desert to San Diego, the one running north of Carrizo Mountain by way of Julian and the other south of the mountain by way of Jacumba and Campo, are still much used for direct communication between the Imperial Valley and the coast, although the Campo road below Mountain Springs is rough and after storms is nearly impassable.

EARLIER WORK

As yet there has been no detailed work done on the geological problems of the extreme southern part of California. Two important reconnaissances, however, have been carried out in that region and a number of other papers contain interesting notes.

Professor William P. Blake,[2] who accompanied one of the Pacific Railroad survey parties under Lieutenant Williamson through Southern California in 1853, wrote a comprehensive account of the

[1] *Nat. Geol. Mag.*, XVIII, No. 12, 830. In a note in this number of the *National Geographic Magazine*, Professor Blake proposes that the name Lake Cahuilla be applied to the vanished water body whose earlier existence is clearly proven by so many phenomena and whose history was first deciphered by Professor Blake himself. The name is most appropriate and the suggestion is most appropriately made by this distinguished worker.

[2] *Pacific Railroad Reports*, "Geology" (1856), V.

region which he visited and made a number of contributions of permanent value. He explored the Colorado desert, studied the effects of wind erosion in it, examined the old water-line which is so conspicuous a feature on the west side of the valley opposite Coachella and Walters, and worked out correctly both the origin of the lake whose former presence is attested to by it and the cause of this lake's disappearance.

Professor Blake made three trips along the valley of Carrizo Creek with the expedition, and brought out a few fossils which he collected from one of the flat, sandstone-capped hills on the north side of the valley. These were examined by Mr. T. A. Conrad, who pronounced the species new but probably of Miocene age.

Dr. Harold W. Fairbanks[1] visited Carrizo Mountain in the early nineties for the California State Mining Bureau, and while the exigencies of publication were such that a complete expression of his observations and conclusions was not possible, his paper is none the less very definite and satisfactory. He made hurried trips to the slopes of Black Mountain, which lies north of Carrizo Creek, and to Carrizo Mountain itself, and made collections from each locality. He described the fossils and the general geology of the district, and mentioned the corals which occur at the base of the sedimentary section.

Dr. Stephen Bowers,[2] of Los Angeles, visited the west side of the Colorado Desert in the summer of 1901, for the California State Mining Bureau. At that time there were a number of companies in the district drilling in the sedimentary rocks for oil. It was in connection with this oil excitement that Dr. Bowers' visit was made. He secured some fossils from the Carrizo and Black mountain localities which were submitted to Drs. Merriam, Vaughan, and Arnold. The interest aroused by these small collections led to the planning of the trip described here.

Other writers on the Colorado Desert have devoted themselves to general observations or to the description of particular features outside the Carrizo Mountain region. Among them may be mentioned:

[1] Fairbanks, H. W., *11th Rept., State Mineralogist of California*, 1893, 88, 90.

[2] Stephen Bowers, *Reconnaissance of the Colorado Desert Mining District*, California State Mining Bureau, 1901.

H. G. Hanks, "Mud Volcanoes and the Colorado Desert," *2d Ann. Report, State Mineralogist of California*, 1880–82, 227–40.

Chas. R. Orcutt, "The Colorado Desert," *10th Ann. Report, State Mineralogist of California*, 1890, 899–919.

Dr. Robt. E. C. Stearns, "The Fossil Freshwater Shells of the Colorado Desert, Their Distribution, Environment and Variation," *Proc. U.S. Nat. Museum*, XXIV (1902), 271–300.

GEOLOGY

GENERAL

Carrizo and Black mountains are islands of granitic and metamorphic rocks, which rise through encircling terranes of later sediments and volcanics. These later beds are Miocene and younger, and the unconformity which exists between them and the older rocks upon which they lie is profound. The time interval represented by this unconformity is not known because the age of the altered rocks below it is a matter of uncertainty. Fairbanks[1] expresses the opinion that they are Carboniferous or older, the opinion being based presumably upon their general resemblance to upper Paleozoic rocks in other parts of California and upon the aspect of some shells found in a float piece of siliceous limestone. Accepting this determination as the best possible in the present state of our knowledge, we must conclude that the Triassic, Jurassic, and Cretaceous systems are without depositional representatives in this region. Either the Carrizo and Black mountain areas were land masses subject to erosion during this interval or the evidence of such periods of deposition as intervened was later removed by erosional processes.

The Miocene seems to have been inaugurated by volcanic activity. On the southern slopes of both Carrizo and Black mountains are bedded tuffs, volcanic conglomerates, and less extensive masses of dark lavas of andesitic aspect. On Black Mountain there are distinct sandstones interbedded with these and directly upon them lie the Miocene coral reefs. In Alverson Canyon, which drains south from Carrizo Mountain, red vesicular lavas are succeeded by green and lavender sandstones and conglomerates, whose constituent materials are volcanic, and these in turn grade into conglomerates

[1] Fairbanks, H. W., *11th Rept., California State Mineralogist*, 1893, 88, 90.

with a diminishing proportion of volcanic pebbles. Above them are quartz conglomerates, tawny sandstones, and finally soft greenish-yellow clay shales.

An unconformity which is not especially conspicuous exists in the Miocene between the sandy shell-bearing beds, 100 feet or less in thickness, which immediately overlie the volcanics or the metamorphics, and the great mass of shales, greenish or yellowish at base, pink or pale red in general color-tone toward the top, which form the bad-land area (Fig. 2) that is especially well developed between

FIG. 2.—Lower Garnet Canyon and the adjacent bad lands cut in Miocene shales.

Black and Carrizo mountains. Finally, across the planed edges of these shale beds, a sheet of river cobbles, well rounded, has been distributed unconformably throughout the Carrizo Valley. They are probably Pleistocene, but are earlier than the silts, sands, and gravels, which represent the offshore and beach deposits of the lake which until recently has occupied the Colorado Desert. The latest erosion has left these old stream deposits stranded upon the remnants of the earlier valley floor at heights of from 100 to 200 feet above the present bed of Carrizo Creek.

DESCRIPTIVE

Basal series.—The core of Carrizo Mountain (Fig. 9) is a series of metamorphic rocks in which a blue or gray crystalline limestone is

predominant. Fairbanks reports that the limestones constitute the mass of the north face of the mountain. They are likewise present in great force on the divide between Alverson and Garnet canyons, where bands of graphitic schists are associated with them, but southwest along the first-named canyon, bands of dark biotite gneiss, which presumably represent early intrusives in the limestone, are abundant. Other fresh, dark, fine-grained intrusives, which may be related to the Miocene effusives, are found in narrow dikes.

FIG. 3.—Alverson Canyon and the west slope of Carrizo Mountain.

The bedding of the marmorized limestones and the imperfect foliation in the gneisses are approximately parallel to each other and to the longer axis of Carrizo Mountain. They usually are nearly vertical, the dips in either direction being 70 or 80 degrees.

The basement of Black Mountain was observed at only a few points where the fundamental rock juts out into Barrett Canyon. Here it is a granitic plutonic, with little or no evidence of the action of metamorphic forces. Fairbanks, who examined it at a point somewhat farther east, also speaks of the rock as a granite.

Effusives.—West of Alverson Canyon (Fig. 3), along the north slope of Carrizo Mountain, is a conspicuous exposure of ashy, laven-

der-colored tuff, which appears to lie directly upon the metamorphic rocks. Within the canyon itself and about midway of its length, an exposure of the variegated lava, andesitic in character, has at its base a thin bed of sandstone and conglomerate, while near the mouth of the canyon the sedimentary beds rest directly upon 50 feet of tuffaceous beds, which in turn overlie the older rocks.

No effusives were observed in the Garnet Canyon section on the north slope of Carrizo Mountain, but across Carrizo Creek, in the

FIG. 4.—View down Alverson Canyon from the south-slope of Carrizo Mountain.

upper part of Barrett Canyon and especially in the ridge which separates Barrett Canyon from Deguynos Canyon, just west of it, is a heavy development of the lavas and tuffaceous beds.

Here, as on the south slope of Carrizo Mountain, there is some interbedding of sandstones with the flows, which evidently issued contemporaneously with the beginning of Miocene sedimentation. These interbedded sandstones are usually bright red or pink in hue, as though partly baked by the succeeding lava stream; hence they make conspicuous exposures among the more somber lavas. The uppermost lava flow, upon whose upper surface lies the coral reef (Fig. 6) at the head of Barrett Creek, is about 200 feet thick, and overlies a sandstone bed 20 to 50 feet thick. Below this more effusives extend below the bottom of the arroyo.

In this region the accumulated effusive materials are best displayed in maximum thickness in the ridge that has been mentioned between Barrett and Deguynos canyons. They must be more than 500 feet thick here. In Alverson Canyon their mass is much less.

Miocene conglomerates.—In the lower part of Alverson Canyon (Fig. 4) a heavy conglomerate bed 120 to 130 feet thick overlies a series of tuffaceous strata. This bed is composed of coarse material at the base but becomes finer toward the top. It is only moderately hard and along its upper margin is an abundantly fossiliferous horizon. Splendid coral heads are imbedded in these sandstones, and more delicate forms are found at the base of the superjacent sandy shales. These corals with the molluscan remains that accompany them, all of which await detailed examination and determination, prove the age of the inclosing rocks to be upper Miocene.

On the north slope of Carrizo Mountain, about the head of the eastermost arroyos which are tributary to Garnet Canyon, another series of fragments of a well-developed basal conglomerate are encountered. They extend well up the slopes of the older metamorphic rocks which form the axis of the mountain and dip away from it toward the north or northeast at the rate of 20 or 30 degrees. Being more resistant to weathering agencies than the soft overlying shales, these have been stripped from the sandstones at many points so that the old Miocene beach (Fig. 5), its sands indurated and its teeming life preserved only in fossil form, but yet exhibiting much the aspect and much the same relations which existed at the time of its deposition, is revealed for the modern student's inspection. These basal sands are not always found where their horizon is exposed. In many places the fine clays that were spread out over the sandstones were deposited directly upon the metamorphic rocks that form the core of the mountain and must at one time have formed the bottom and shores of the Miocene sea. The simplest interpretation of this relation is to suppose that before that change of conditions was complete which substituted muddy brackish water with oyster colonies for clear sea water and marine life, the sands of the earlier beach had been swept away, so that there is unconformity, without discordance, or at least without marked discordance in dips, and without a great time interval between the deposition of the sands and

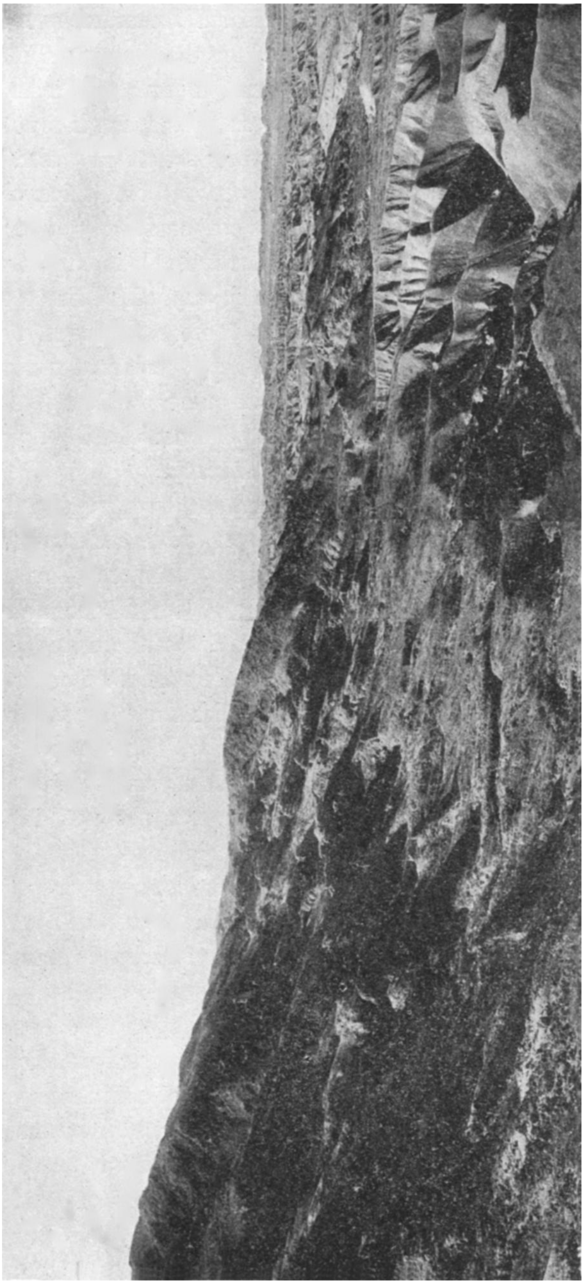

FIG. 5.—Sandstones representing the Miocene beach on the north face of Carrizo Mountain.

the deposition of the muds. The other hypothesis, namely, that these beach sands and the muds were deposited contemporaneously, because of differing local conditions, is made difficult to apply because the two physically different terranes overlie the basement rocks at very closely adjacent points, with no obvious explanation as to why such different conditions should have prevailed so near together.

The heavy sandstones occur at a number of places along the north slope of Carrizo Mountain, east of the head of Garnet Canyon. Many arroyos are incised in them, the stream channel in some cases being a mere notch but a few feet wide and a hundred or more deep. Fossils, however, have not been reported in numbers except at the head of Garnet Canyon.

At the head of Barrett Canyon, which drains south from Black Mountain, the same general relations prevail that have been described in the area a dozen miles to the south on the slopes of Carrizo Mountain. But the fragments of the basal beds of the Miocene are even more widely scattered, and the sandstones and conglomerates are not so fully developed.

About 4½ miles above the mouth and one-half mile above the forks of the Arroyo, the basal beds of the Miocene flank the older rocks and extend across the valley from the west fork to the east fork. Dips here are 20 to 40 degrees to the south, i.e., away from the mountain. The beds are not so thick as on Carrizo Mountain but are succeeded, as is the case there, by soft yellow shales.

About a mile above this point, in a little cove at the head of a small western tributary of Barrett Creek, other outcrops of basal sandstone and conglomerate, not more than 10 feet thick, occur with the underlying igneous rocks all about them. Near this outcrop is a fossil coral reef lying directly upon the lavas and isolated from all the other sedimentaries (Fig. 6). A half-mile farther north a sheet of sandstone, folded into a basin and thus somewhat protected from erosion, still exists. Doubtless many other similar fragmental exposures would be revealed by more extended search.

Miocene shales.—Flanking Carrizo Mountain on nearly all sides and extending on the southeast practically to Signal Mountain, on the international boundary, are continuous exposures of the beds which overlie the basal conglomerate. They are well developed also

on the southwest slopes of Black Mountain. The middle drainage basin of Carrizo Creek is a bewildering bad-land area (Fig. 7) formed by the sharp dissection of these soft clays. For many hundreds of feet above the conglomerate, the shale beds contain only occasional strata of thin brown nodular sandstone, hence they form smooth clay hills. They are entirely destitute of vegetation because of the aridity of the region, so the area in which they are found is desolate in the extreme. Fresh outcrops of the shales are to be seen only

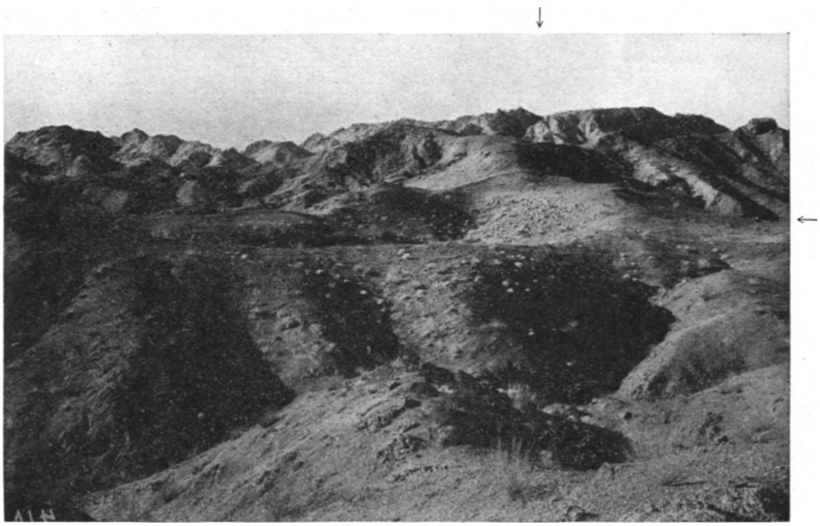

FIG. 6.—Fossil coral reef near the head of Barrett Creek.

along the flood channels where there has been recent cutting. Ordinarily each shale hill is mantled by several feet of residual material, dust much the greater part of the time, soft adhesive mud during the occasional desert rains. This mantle is the result of the weathering of the soft shales. Exposed to the air, they disintegrate completely and rapidly. This action is probably aided by the efflorescence of certain of the alkali minerals which are abundant in the shales. Wherever a thin sandstone is interstratified with them, it partially preserves them from the rapid disintegration which ordinarily affects them and so usually caps a hill which stands above the general level of the unprotected shale. Such low structural monadnocks are numerous in the neighborhood of Barrett's Well (Fig. 2).

Farther to the east and south, as in the vicinity of the Yuha Oil Well, at horizons which are presumably higher than those in the Carrizo Valley, although the conditions governing our brief reconnaissance were such that it was not possible to determine the relations with any certainty, the sandstone beds are more abundant. Many of them here weather in curious nodular forms of great variety. Such forms have been well described by Professor Blake.[1]

FIG. 7.—Erosion in the Miocene shales of the Carrizo Valley.

The Carrizo Valley is synclinal, the shales rising gently northward and southward from the axis of the valley toward the bases of Black and Carrizo mountains. Near the borders dips of 5° to 20° were measured, while in the center of the valley the beds are nearly horizontal or exhibit irregular attitudes. Faults of small displacement were noticed near the head of Garnet Canyon, others north of Carrizo Creek have been described and figured by Blake, and Fairbanks believes that the abrupt eastern face of Black Mountain overlooking the desert is a fault scarp.

In the vicinity of Yuha Oil Well more pronounced structures

[1] "Explorations and Surveys for a Railroad Route from the Mississippi River to the Pacific Ocean" (War Dept., 1857), *Geological Report* by Wm. P. Blake, p. 102.

exist, at least one district anticline with a northeast-southwest axis having been observed half a mile south of the well.

No attempt was made to measure the thickness of these beds, but the buff clays in the middle Carrizo Valley must aggregate 1,000 feet or more, and the beds with a distinctly reddish tone, which are more prominent above Carrizo Station and southeast of Carrizo Mountain, overlie them. The oil well at Yuma starts in sandy strata which appear to be stratigraphically higher than the reddish clays, and at

FIG. 8.—Old water-line marking the shore of Lake Cahuilla west of Coachella.

the time of our work in January, 1904, had penetrated over 700 feet of alternating sandstone, shale, gypsum, and shell beds.[1] The thickness of the basal conglomerate on either side of Carrizo Mountain is about 200 feet, as indicated in the generalized sections of Garnet Canyon (Fig. 10).

Superficial deposits.—The shale bluffs along Carrizo Creek, 50 to 100 feet high, are capped in many cases by a deposit of river cobbles three to ten feet in thickness. These cobbles are distributed over practically all of the lower shale hills within the valley whose tops are broad enough to retain the alluvium. Dissection has been so

[1] This well was afterward deepened to about 1,200 feet, but the full record is not available.

complete that the majority of these summits are reduced to mere points and lines. In these cases the arroyos and the slopes below the summits are often cumbered with the river wash which has slumped down as the hills have been reduced, but has not yet been removed. This material represents a variety of metamorphic and igneous rocks probably derived from the Peninsula Range and its outliers. Its deposition dates back to an earlier erosional cycle, when the present tops of the bad-land hills formed the bottom of the valley of the ancestor of Carrizo Creek.

Within Carrizo Valley proper and in the lowland south of Carrizo Mountain, there is the usual desert accumulation of washed material

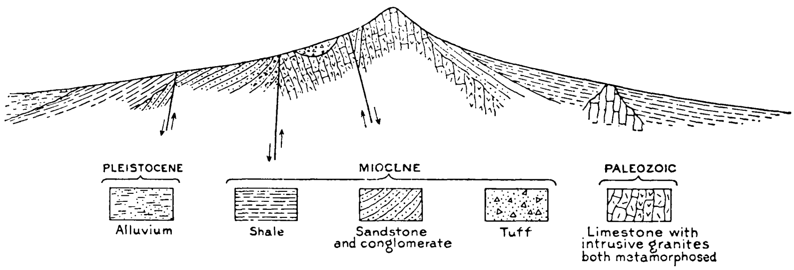

FIG. 9.—Diagrammatic section across Carrizo Mountain by way of Alverson and Garnet Canyons.

grading upward toward the mouth of each canyon into alluvial cones. West of Carrizo Station and at other favorable points in adjacent parts of the desert, there are many sand dunes, but these reach a greater development in the more open desert to the north and east.

Passing eastward beyond the valley of Carrizo Creek toward Imperial, the road at first traverses areas of well-reduced shales and sandstones, and then reaches a broad zone of beach gravels full of well-preserved shells of modern types.[1] This zone represents the beach line of the extinct lake that once occupied the Colorado Desert. The beach is not as distinct as a physical feature here as at many points farther to the north (Fig. 8) because the shore line

[1] Robt. E. C. Stearns, Ph.D. "The Fossil Freshwater Shells of the Colorado Desert, Their Distribution, Environment, and Variation," *Proc. U.S. Nat. Museum*, XXIV, 271–99.

itself was shelving and indefinite, but its general position is well marked by the molluscan remains.

Beyond and below the gravel zone is one of sand, and still farther east beyond this is the silt-covered bottom of the old lake Cahuilla. The deposits here are impalpably fine, laminated clays which, when stirred, as in a much-traveled road, become a tawny flour and when moistened are transformed into a smooth, adhesive mud.

RÉSUMÉ OF GEOLOGIC HISTORY

The story of the development of this part of the country cannot be read with any approach to accuracy as yet for any period beyond the Miocene. The rocks which represent earlier time are marmorized limestones, schists, and gneisses as to whose age there is much doubt. The slight existing evidence points toward the Carboniferous as the period during which the limestones were deposited here. Whatever their age, their condition now indicates that their history previous to the Miocene was one involving deep burial and intense earth strain. They were upturned, intruded, and crystallized, uplifted and eroded into a mountainous topography, and at the beginning of the late Miocene formed islands in a sea teeming with life. Volcanic forces were active at this time and the flanks of the old land mass are partly buried under the effusive material which issued then, and the muds and the littoral whose fragments were supplied from volcanic sources are conspicuous at many points. But as the period advanced, vulcanism ceased and the present Carrizo and Black mountains were surrounded and perhaps for a part of the time were submerged beneath a clear sea in which the myriad forms of the life of the period swarmed. Still later in the Miocene the character of the sea changed. Instead of clear, salt water, some re-alignment of forces caused great quantities of muddy brackish water to spread about the old islands. Oysters of many forms, some of them of great size, some very tiny indeed, flourished. The heavy silts of these muddy waters accumulated to great depths as the land subsided. Finally the waters withdrew, presumably because of re-elevation, and the region was land again as it had been before, and the shells of many of the creatures which had lived in the clear and then in the muddy waters were preserved in the accumulated

sediments. As the sea withdrew, the destructive forces of weathering and the erosive forces of wind and running water became active. The clays which had accumulated were now dry and were cut away again by these forces. The process was not long continued and the plain was not completed, those clay areas which were capped by protecting sandstones remaining as monadnocks above the wide valley floor. This valley, occupied by an earlier vigorous ancestor of Carrizo Creek, was strewn with rounded river cobbles brought from the higher mountains to the west. South and east of Carrizo Mountain large areas seem to have been reduced at this period well toward the condition of a peneplain. This plain lies perhaps two hundred feet above the later Pleistocene lake-level with which it seems to have no connection. It is regarded as an earlier independent feature, perhaps Pliocene in age.

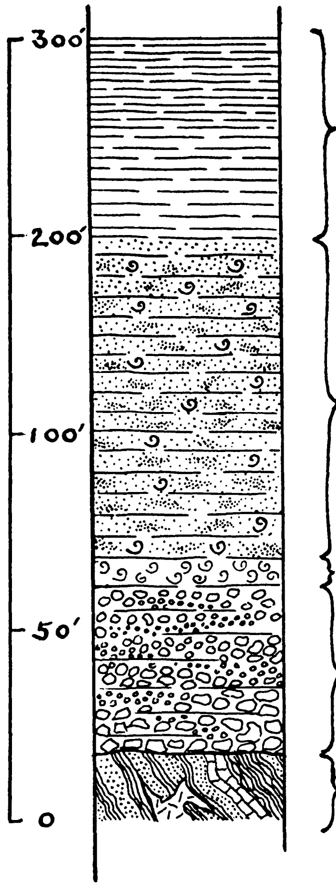

FIG. 10.—Columnar section of rocks exposed in Garnet Canyon.

After the formation of this partially planed surface, over the soft rocks of Carrizo Valley, some change either in the relations of land and sea, or of climatic conditions, enabled the streams to dissect it again. The result of this dissection, which may well have been contemporaneous with the last occupancy of the Colorado Desert by the Gulf of California, is seen in the Carrizo Creek bad lands of today.

The last important element in the development of the geography of this part of the desert was the formation and the disappearance of the desert lake. So late is it, that the calcium carbonate incrustations which it left on its western shore (Fig. 8) show but little

effect of erosive or solvent action since the waters left them, and the sandy beach, molded by the waves of the lake upon the alluvial fans which formed a large part of its shores, is still well enough preserved to be readily traced. Only the most modern gullies have cut it away. At one point a low sea cliff notched by the waves in steep alluvial-fan material still stands, as perfectly preserved as though the waters had just withdrawn.

CONCLUSION

In conclusion it is to be said that but the barest outlines of the history of this fascinating region are yet known. Its rocks contain a rich upper Miocene fauna, probably in large part new, and its exposures and structures are so clear that its geology will be an open book to the fortunate student to whom falls the pleasant task of deciphering it in detail.

FOSSIL LOCALITIES[1]

Shells are very abundant in the vicinity of Yuha Oil Well, but the variety is not as great here as at other localities where collections were made. A few hundred yards west of the well is an outcrop of an oyster bed which makes a conspicuous shell mound and other similar outcrops exist in the vicinity.

The horizon is the highest at which collections were made. It is probably a few thousand feet above the Carrizo and Black mountain horizons. Collections Nos. 160 and 161 were made near Yuha Well, and No. 162 was made about one and one-half miles southeast, but the horizons are not believed to be far apart.

Collection No. 165 is from a point about two miles east of the base of Carrizo Mountain. Shells are abundant here but species are limited, as is true of the vicinity of Yuha Well. These shells are probably stratigraphically lower than collections Nos. 160–62 but are higher than the others except possibly No. 168.

Collection No. 168 was made on the county road, near Barrett's Oil Well. The locality is nearly midway between Carrizo and Black mountains and must be from substantially the same horizon as Blake's original collection. It is also near the horizon of No. 165, but may be slightly lower.

No. 163 is from a small arroyo just east of Alverson Canyon, on the south side of Carrizo Mountain. The shells were taken from the yellow clays which immediately overlie the basal conglomerate. These clays contain a rich fauna which is not by any means fully represented in the collection. Stratigraphically these beds belong above the three collections yet to be mentioned. The length of the time interval between the two horizons depends upon the extent of the

[1] These descriptive notes are introduced for the use of the paleontologists who may eventually study the collections now in the U.S. National Museum.

unconformity between the conglomerates and the clays. It is probable that this interval is slight, but there are no data at hand for estimating it.

Nos. 164 and 166 are from Alverson Canyon and the head of Garnet Canyon on the south and north slopes respectively of Carrizo Mountain. The horizons are identical, being in each case the sandstones which form the upper part of the arenaceous series at the base of the Miocene. These are the most conspicuous fossil localities in the region. The shells or their casts have weathered out and strew the slopes in great profusion. Corals, echinoids, ostrea, pectens, strombus, and malea are everywhere. The matrix, however, is coarse, and only large and robust types are well preserved. The locality has been noted by prospectors generally, because the occurrences are so conspicuous.

No. 167. This collection consists of corals almost entirely. The fossil reef is near the head of Barrett Canyon and lies directly upon the igneous rocks which served as a basement for Miocene sedimentation at this point Whatever later beds may have originally covered it have been stripped away, so that the old reef is now isolated. There can be little doubt, however, that its position is at the base of the Miocene series and substantially equivalent to that of Nos. 164 and 166.